

19p

UARI RESEARCH REPORT NO. 17

FACILITY FORM 801

N64-29403

(ACCESSION NUMBER)

(PAGES)

(NASA CR OR TMX OR AD NUMBER)

(THRU)

(CODE)

(CATEGORY)

## GROOVE GUIDE MEASUREMENTS

UNCLASSIFIED PRELIMINARY DATA

by

F. J. Tischer

F. W. Someroski

OTS PRICE

XEROX

\$

MICROFILM

\$

1.60ph

This research work was supported by  
the National Aeronautics and Space Administration  
partially funded under NsG-381.

UNIVERSITY OF ALABAMA RESEARCH INSTITUTE  
Huntsville, Alabama

August 1964

REPORTS CONTROL No. 3

## GROOVE GUIDE MEASUREMENTS

by

F. J. Tischer and F. W. Someroski

29483

Summary: Results of an experimental study of the "Groove Guide" are presented. The guide consists of two parallel conducting strips, each with a centrally located longitudinal groove facing each other. The field distribution, guide wave length, and the attenuation were measured in specially designed test setups. The test setups and measurement circuits are described and the measurement results discussed.

Auth.

## Introduction

In a preceding paper,<sup>1</sup> a nonconventional wave guide, called "Groove Guide", was described. This guide consists of two parallel conducting strips with centrally located grooves facing each other as indicated in Figure 1. The field distribution in the guide, which is a maximum in the center, decreases exponentially toward the upper and lower openings. The guide can thus be open and only a negligible fraction of the energy is radiated.

If waves of the transverse-electric ( $TE_{10}$ ) fundamental mode with the E-vector parallel to the walls are excited, the guide has reduced attenuation in comparison with the standard rectangular wave guide. Methods for the theoretical consideration of this guide were discussed by Tischer<sup>2,3</sup> based on conformal mapping and by Ruddy<sup>4</sup> by evaluation of the impedance-matching concept.

In the present paper, results are presented of an experimental study of groove-guide structures carried out at the University of Alabama Research Institute in Huntsville, Alabama. The transverse decrease of the field intensities in direction from the center of the guide, the guide wave lengths, and the attenuation were measured to verify the guide concept and some of the theoretically obtained results. The measurement setup also permits the study of the launching of waves in the groove guide and the effects of discontinuities.

---

<sup>1</sup> Tischer, F. J., The Groove Guide, A Low-Loss Waveguide for Millimeter Waves, 1963 WESCON, San Francisco, August 20-23, 4.5

<sup>2</sup> Tischer, F. J., Conformal Mapping in Waveguide Considerations, Proc. IEEE, Vol. 51, p. 1050, July 1963

<sup>3</sup> Tischer, F. J., The Groove Guide, A Low-Loss Millimeter Wave Guide, Millimeter and Sub-Millimeter Conference, Orlando, Florida, January 7, 1963

<sup>4</sup> Ruddy, J.M., The "Groove" Guide, Memorandum No. 89, July 3, 1963, Polytechnic Institute of Brooklyn

### Measurement of Field Distributions

Field-distribution measurements were carried out according to several principles and the results compared. In one case, the field distribution was measured in a specially designed parallel-wall section shown in the upper portion of Figure 2. This figure shows the test setup and the measurement circuitry. The test section has grooves facing each other in the center of the parallel walls. Wooden wedges at the rim between the parallel walls absorb the waves traveling toward the rim and simulate infinite-wall conditions. The waves are launched by a horn radiator into the center part between the parallel walls in the direction of the grooves.

Small holes in the upper wall of the test section permit insertion of a capacitive probe for the determination of the field strength component perpendicular to the walls. The field strength component decreases exponentially in the direction from the center.

The measurement circuitry consists primarily of a microwave bridge circuit for amplitude and phase comparison with a directional coupler at the transmitting end and an E-H coupler at the output. One of the bridge arms is formed by the grooved-wall test section with probe. The probe is connected by cable to the comparison arm of the E-H coupler. The other arm of the bridge contains an attenuator and a phase shifter. Energy is transmitted into this arm by the secondary guide of the directional coupler. The arm is connected to the second comparison arm of the E-H coupler. The E-plane arm of the latter contains the matched crystal holder as a zero indicator.

Theoretically, the exponential decrease of the field intensities in the groove guide in transverse direction parallel to the walls is given by

$$\alpha_y = [ (2\pi/\lambda_g)^2 - (2\pi/\lambda_{go})^2 ]^{1/2} \quad (1)$$

In this equation,  $\alpha_y$  is the exponential decay factor in Nepers per cm if the values of the guide wave lengths are inserted in cm. The guide wave lengths for wave propagation between parallel walls without grooves and the actual groove-guide

wave length are denoted by  $\lambda_{go}$  and  $\lambda_g$  respectively. It should be noted that the phase of the field intensity is independent of the distance from the center. Equation (1) can be derived from the general equation for the propagation constant

$$\Gamma_x^2 + \Gamma_y^2 + \Gamma_z^2 = \Gamma_o^2 ,$$

$$\Gamma_x = \pi/p, \quad \Gamma_y = -j\alpha_y, \quad \Gamma_z = 2\pi/\lambda_g, \quad \Gamma_o = 2\pi/\lambda_o ,$$

which is valid for the parallel wall region above and below the grooved region. The reduction of the guide wavelength by the grooves ( $\lambda_g < \lambda_{go}$ ) causes  $\Gamma_y$  to become imaginary.

Examples of the results of the field strength measurements according to the above principle are shown in the diagrams of Figures 3 and 4. Figure 3a presents contours of constant relative magnitudes of the field intensity in the longitudinal and transverse direction. The amplitude measurements are supplemented by phase measurements. The results of these measurements indicate that the effects of the horn radiator and of the discontinuity between the horn and the guide cannot be neglected. Figure 3b shows the results of the phase measurements. The sinusoidal variations of the amplitudes in the longitudinal direction in the contour plots indicate the same effect. Near the horn, the surfaces of the constant phases are near-cylindrical. This indicates that radial wave components are super-imposed on the actual groove-guide modes.

The exponential decrease of the field intensities in transverse direction is also shown in the diagrams of Figures 4a and 4b. The diagrams show the magnitudes of the field intensities measured at two frequencies (8.257 GHz and 10.003 GHz) at three different longitudinal positions as a function of the distance from the center.

The phase measurements also permit determination of the guide wavelength as a function of frequency. With these values the relative exponential decrease of the field intensities in transverse direction ( $y$ ) can be computed according to Eq. (1).

A second series of field distribution measurements was carried out in a test setup for the determination of the attenuation and the Q-value described later. This test setup consists of a section of an open groove guide with the dimensions  $H = 16.0$ ,  $\Delta h = 0.762$ ,  $p = 2.286$  and  $\Delta p = 0.4013$  cm terminated on both ends by parallel conducting walls. The structure forms a groove-guide resonator. A dielectric sphere suspended by a nylon thread can be moved parallel to the walls of the groove guide in the symmetry plane across the guide. The deviation of the resonant frequency  $\Delta f$  of the groove-guide resonator caused by the dielectric sphere as it is moved in the symmetry plane of the guide from the upper opening through the center toward the lower opening is then proportional to the local electric energy,

$$\Delta f = k |E|^2,$$

where  $E$  is the local electric field intensity. The ratio of the field intensities  $E_1$  and  $E_2$  at two locations a distance  $\Delta y$  apart in transverse direction is hence

$$(|E_2| / |E_1|)^2 = \Delta f_2 / \Delta f_1 = \exp(-2\alpha_y \Delta y), \quad (2)$$

since  $E_2 = E_1 \exp(-\alpha_y \Delta y)$ . The quantity  $\alpha_y$  is the decay constant of the field intensity in transverse direction. Knowing  $\Delta f_2 / \Delta f_1$  and  $\Delta y$ , Eq. (2) permits determination of  $\alpha_y$ .

The results of these measurements are plotted in Figure 5 on semi-logarithmic paper for the frequencies 8.257 GHz and 10.003 GHz for a dielectric sphere as probing element. The curves show the exponential decrease which is characterized by straight lines in the region excluding the center of the guide near the groove and the upper and lower near-edge regimes.

Figure 6 shows the results of an evaluation of the diagram in Figure 5. It presents the transverse decay factor  $\alpha_y$  obtained from the slopes of the curves plotted in these diagrams. The values are indicated by the circles. As a comparison, the values obtained from the measurement of the guide wave length according to Eq. (1) are plotted in curve A.

### Guide Wave Length

The guide wave length  $\lambda_g$  of the groove guide is somewhat smaller than that of a parallel-wall guide without grooves  $\lambda_{go}$ . This reduction is primarily caused by the storage of magnetic energy in the groove related to the longitudinal magnetic field component.

As an approximation, the guide wave length can be computed according to a method outlined in Reference 1. The method can be refined by considering an equivalent H-guide containing a slab of material with an anisotropic permeability such that the longitudinal component of the relative permeability tensor only deviates from the value 1. The various values of the guide wave length of the groove guide are shown in diagram form in Figure 7. The measured values are compared with those obtained by the above approximate computation method. It should be noted that the approximation is good at lower frequencies near cutoff.

### Attenuation Measurements

The attenuation of the groove guide was determined by a resonance method. Hereby, the attenuation is being computed from the measured Q-value of a resonator which contains the wave guide under consideration. The groove-guide resonator contains a section of the guide placed between two parallel conducting walls. The walls reflect the waves traveling in and outside along the groove guide at the ends of the guide section. Energy is fed into the resonator by a small coupling hole in the center of one of the end walls of the guide. The coupling hole connects the resonator to the end of a rectangular X-band wave guide and to a klystron as energy source. Figure 8 shows a photograph of the resonator and of the measurement circuitry.

Several methods for the measurement of the Q-value with swept frequency were tested such as reflection measurements at the input and probe measurements. The probe measurements gave the most reliable results. The probe consisted of a small capacitive antenna placed near the end of the groove-guide section and intruding slightly into the region between the parallel walls. The frequency was swept by a sawtooth signal applied to the reflector of the klystron. Low coupling was used to eliminate loading of the resonator by the wave guide feeding energy into the resonator and by the probe. Displaying the field intensity on an oscilloscope

with the saw tooth as horizontal deflection voltage, the  $Q$ -value can be obtained by the evaluation of the resonance curve. The  $Q$ -value is given by  $Q = f_o / \Delta f$  where  $f_o$  is the resonant frequency and  $\Delta f$  is the frequency difference between half-power points.

The attenuation of the guide is related to the  $Q$ -value of the guide by

$$\alpha \text{ [ Nepers/cm ]} = \frac{1}{2} \frac{\beta}{Q} \left( \frac{\lambda_g}{\lambda_o} \right)^2, \quad (3)$$

where  $\beta = 2\pi / \lambda_o$  is the phase constant and  $\lambda_o$  is the operational frequency.

The test setup was also used for the determination of the guide wave length by finding the number of half-wave lengths along the resonant groove-guide section at consecutive resonant frequencies in the X-band region. Field strength measurements were also carried out in the resonator. The relative field strength within the guide was determined by moving a dielectric sphere through the guide and by measuring the deviation of the resonant frequency as a function of the position of the sphere as discussed previously.

The results of the  $Q$ -value measurements are presented in Figure 9. It shows the  $Q$ -value of the groove guide (A) as a function of frequency. For comparison, the  $Q$ -value of a resonator containing a section of a rectangular guide of equal length and machined from the same material is plotted below (B).

The attenuation of the groove guide (A) computed from the  $Q$ -value according to Eq. (3), is presented in Figure 10 in comparison to that of the rectangular guide plotted in the same figure (B).

The results agree with theory which shows that the groove guide has approximately the same attenuation as a parallel wall guide of the same width. It should be noted that the advantages of the groove guide are in the millimeter-wave region where the width of the guide can easily be increased to oversize dimensions in comparison to the standard rectangular guide. In this frequency range the improvement of the attenuation becomes more pronounced.



## Conclusions

The experimental study of the groove guide with regard to field distribution, guide wave length, and attenuation shows results which are in agreement with the predicted properties and with the theoretical data. The attenuation of the guide is of particular interest. It is found to be approximately equal to that of a parallel wall guide of equal width at the same frequency. For obtaining full benefit of the reduction of the attenuation, the guide has to be oversized, which can be considered as an advantage at millimeter waves, and the difference between the two guide wave lengths  $\lambda_{go}$  and  $\lambda_g$  should be as large as possible.

The study indicates also that the effects of the launching of the groove-guide waves and the excitation of other wave modes needs further study. Optimization of the structure to give minimum attenuation is another topic for additional study. Most of these can be carried out in test setups used for the experiments described, after some modification.

## Acknowledgement

The authors wish to express their appreciation to Mr. Hung Yuet Yee for his assistance in the evaluation of the results of the measurements.

The research was supported in part by the National Aeronautics and Space Administration under NsG-381.

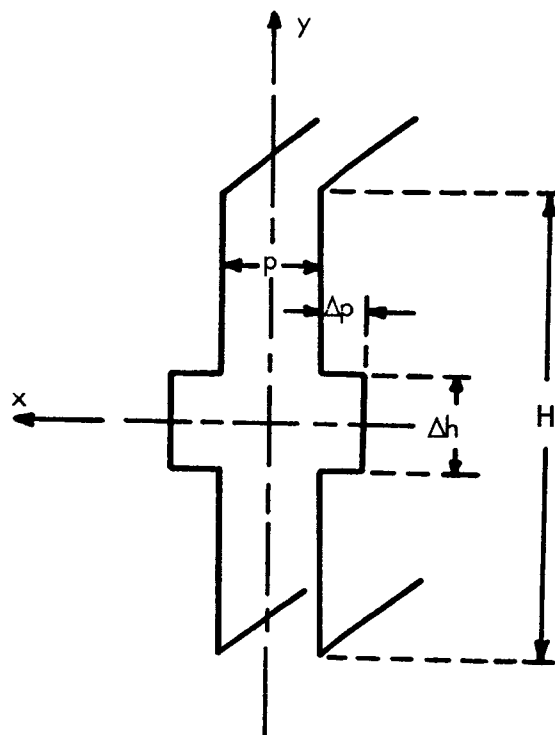


Figure 1 - Groove guide cross section

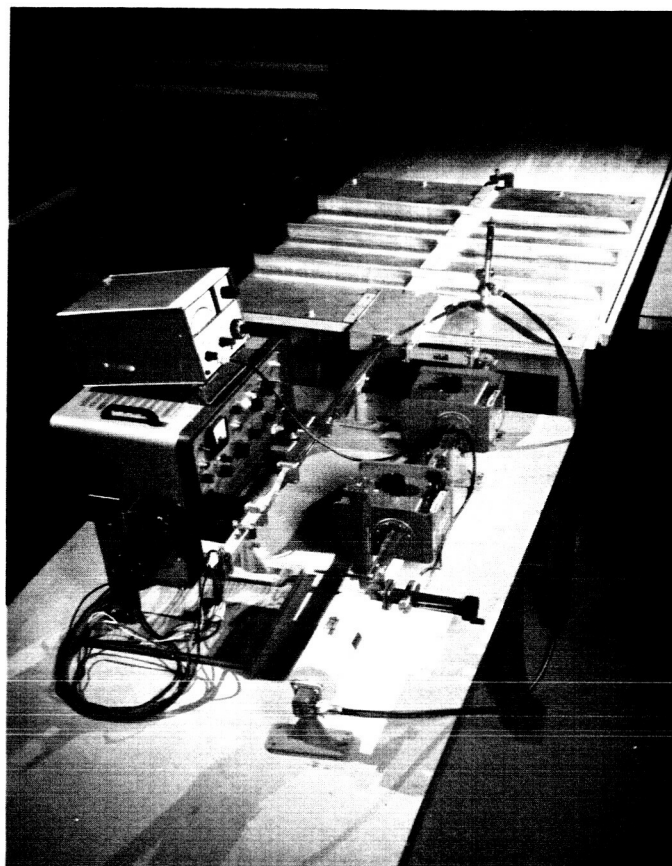


Figure 2 - Test setup for the measurement of the field distribution

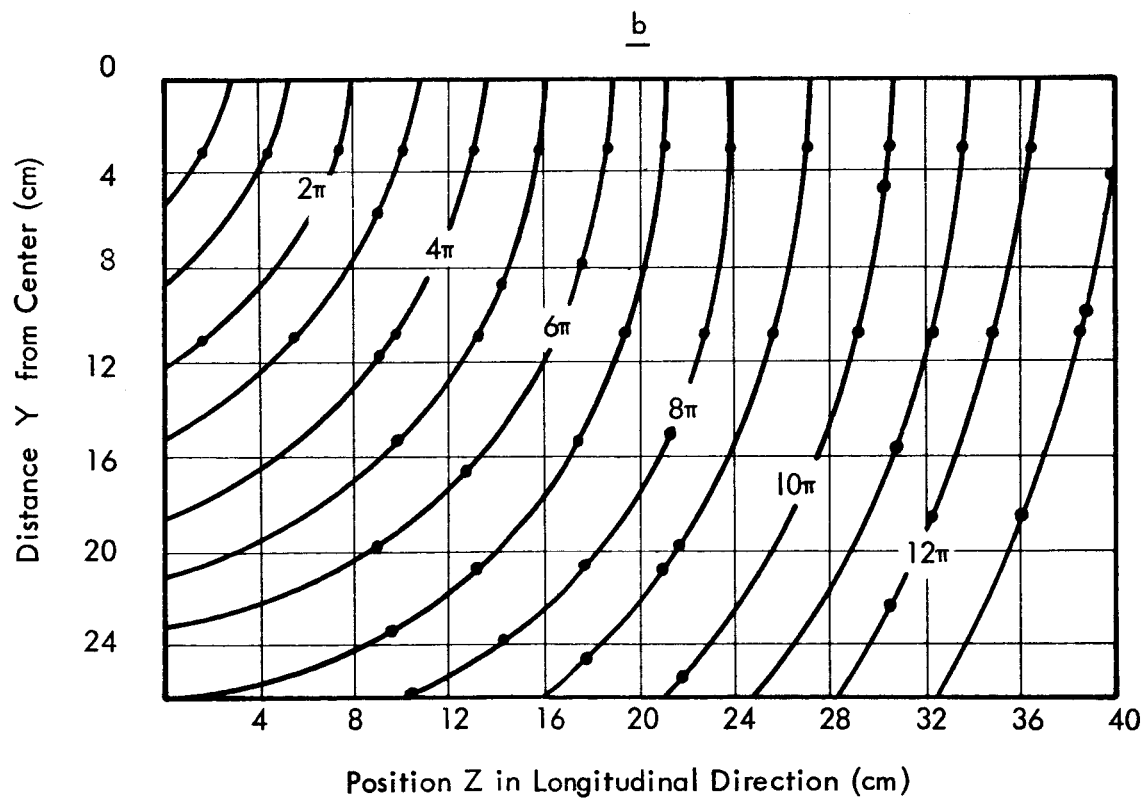
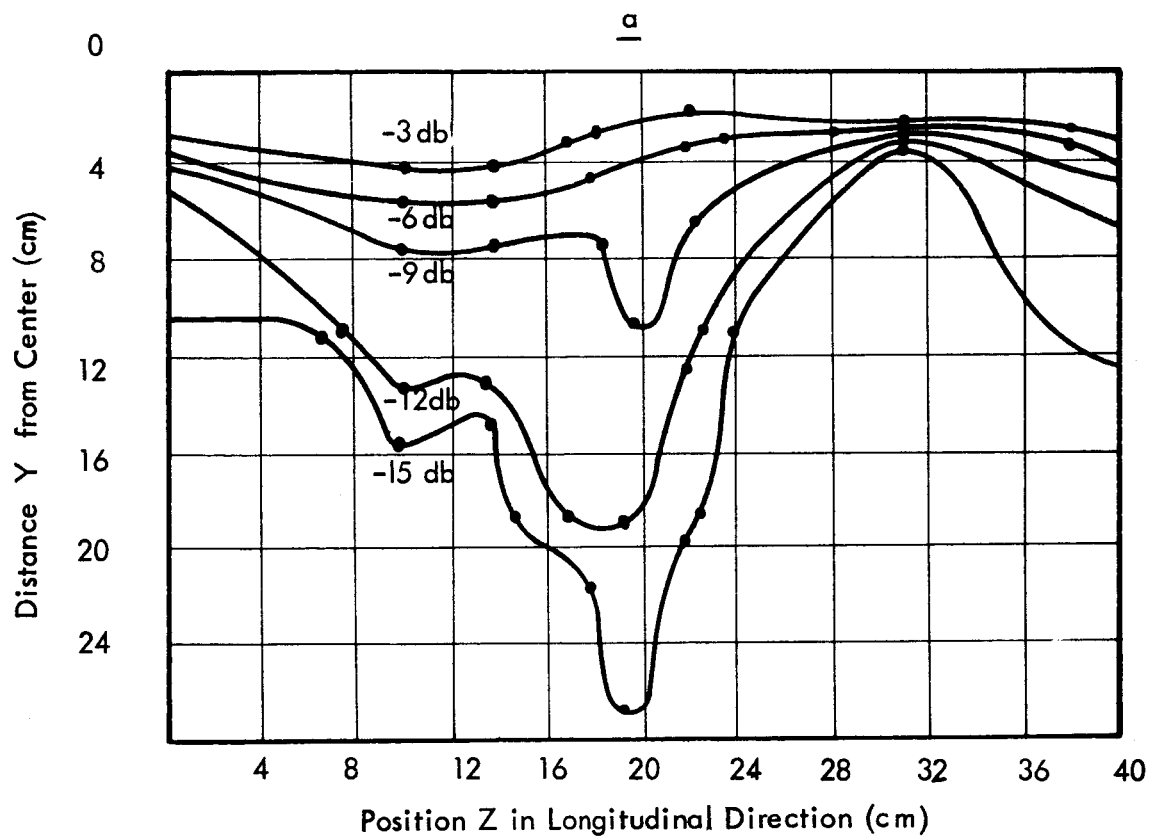


Figure 3 - Loci of constant field magnitudes at 8.257 GHz  
a. Amplitude  
b. Phase

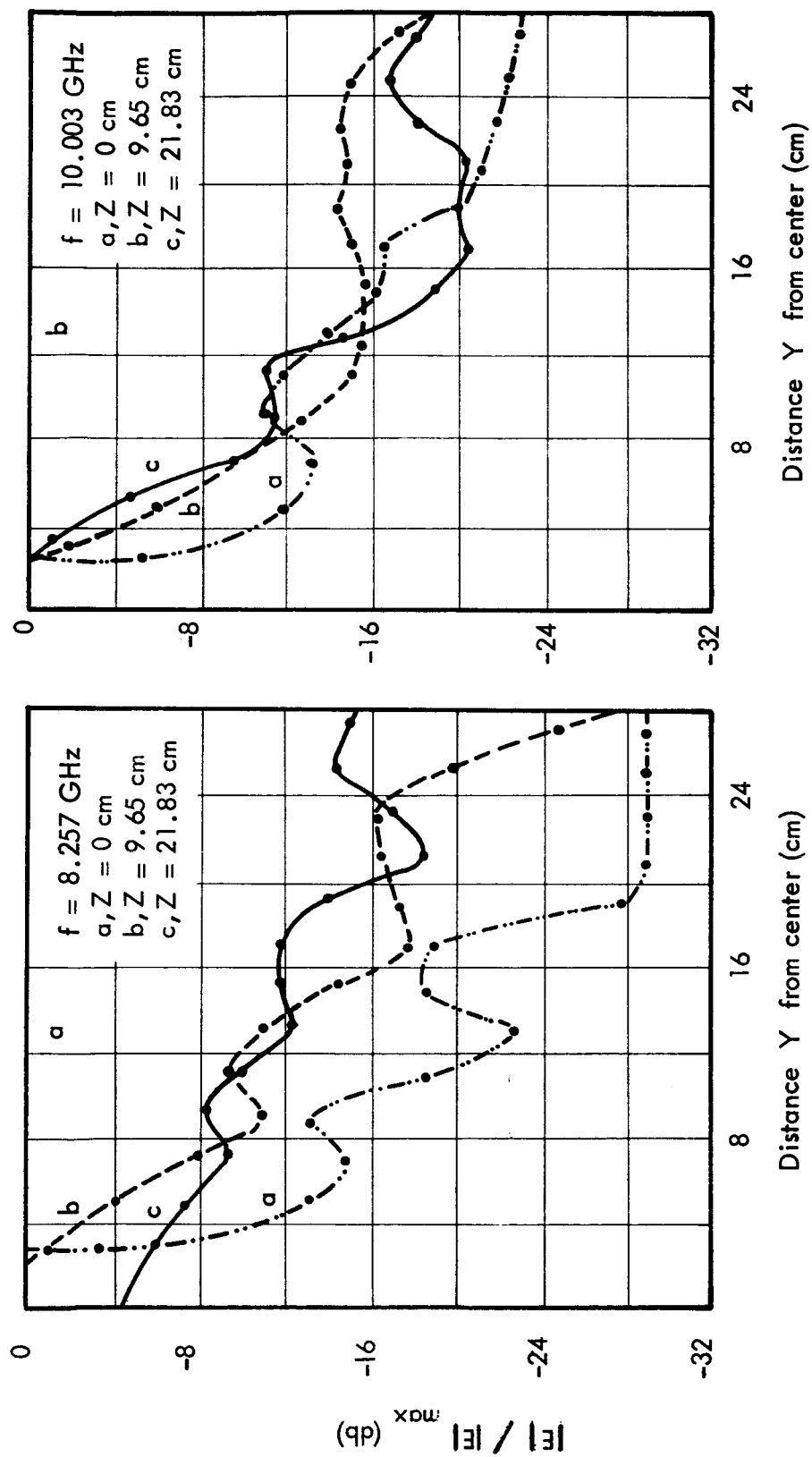


Figure 4 - Relative field intensity versus distance from the center axis  $Y$ .

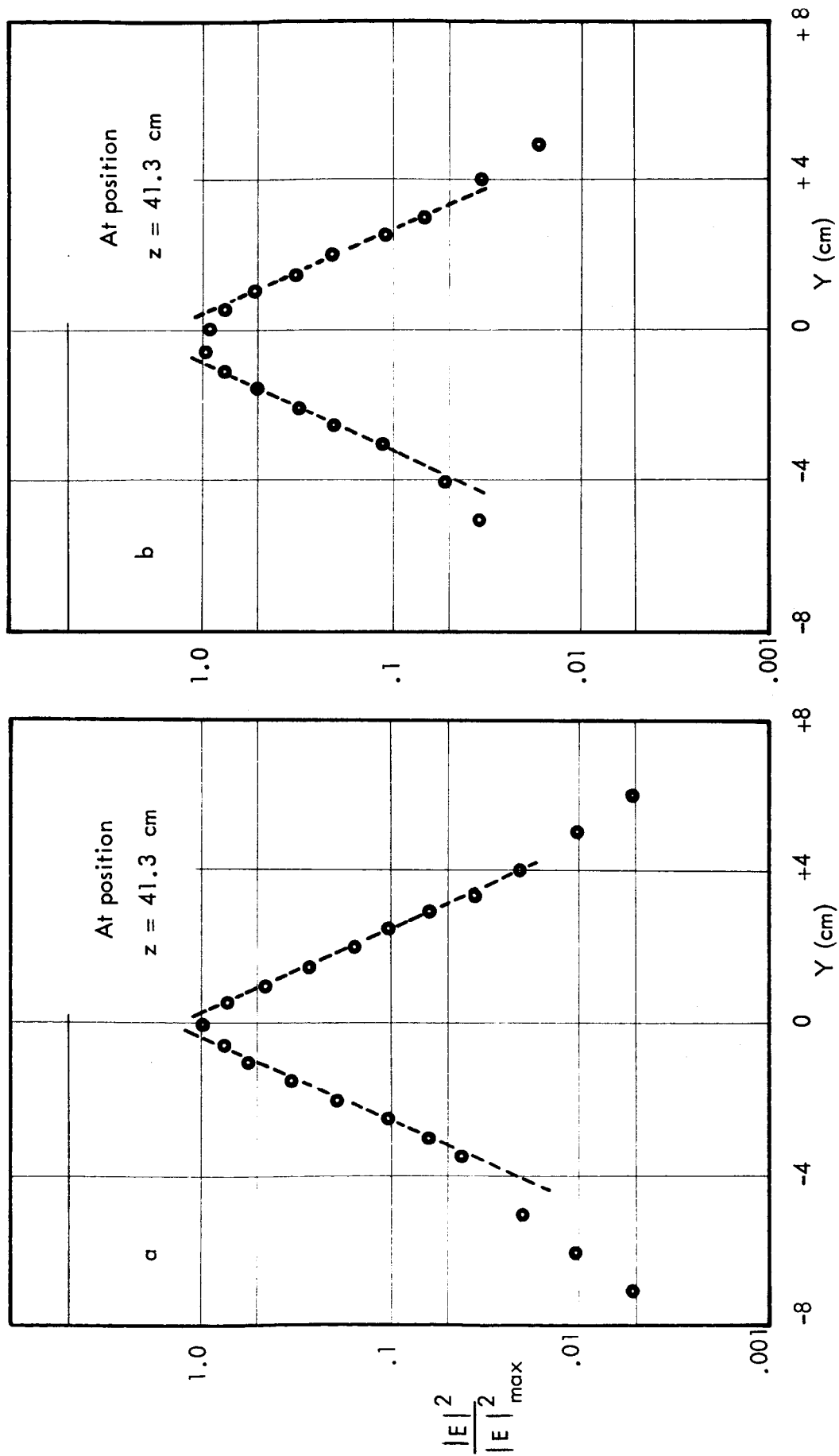


Figure 5 - Relative field intensity as a function of the distance from the center axis of the groove guide for, a ( $f_0 = 8.253$  GHz) and b ( $f_0 = 10.026$  GHz) measured with dielectric sphere.

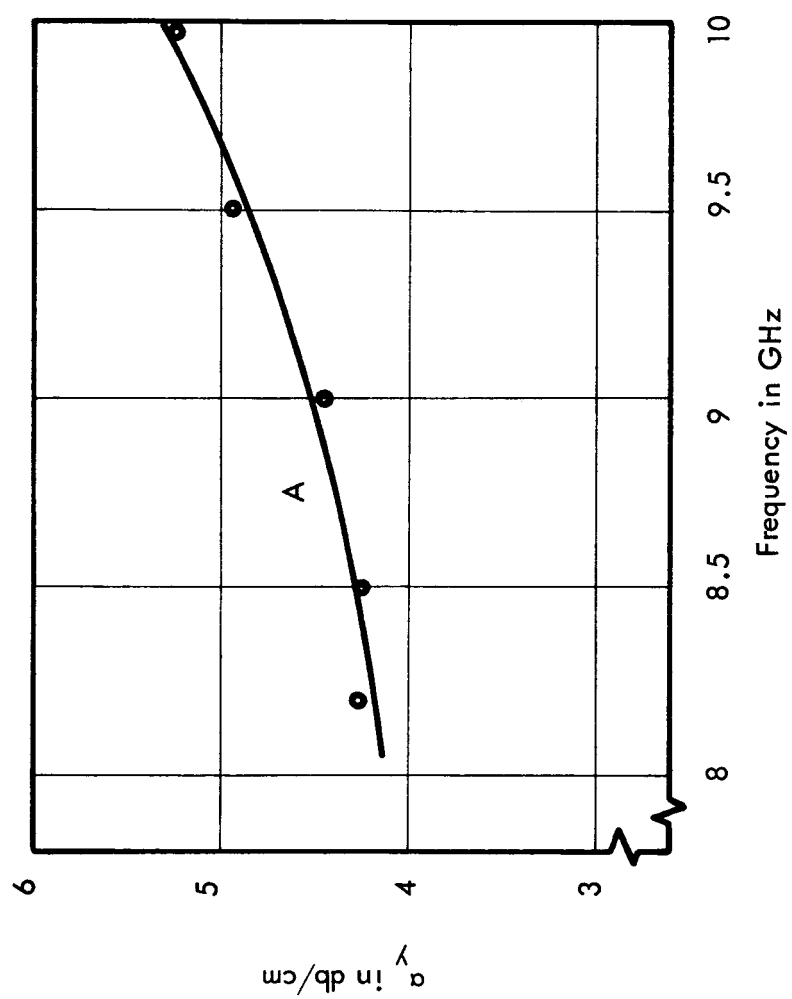


Figure 6 - Transverse decay factor  $a_y$ .

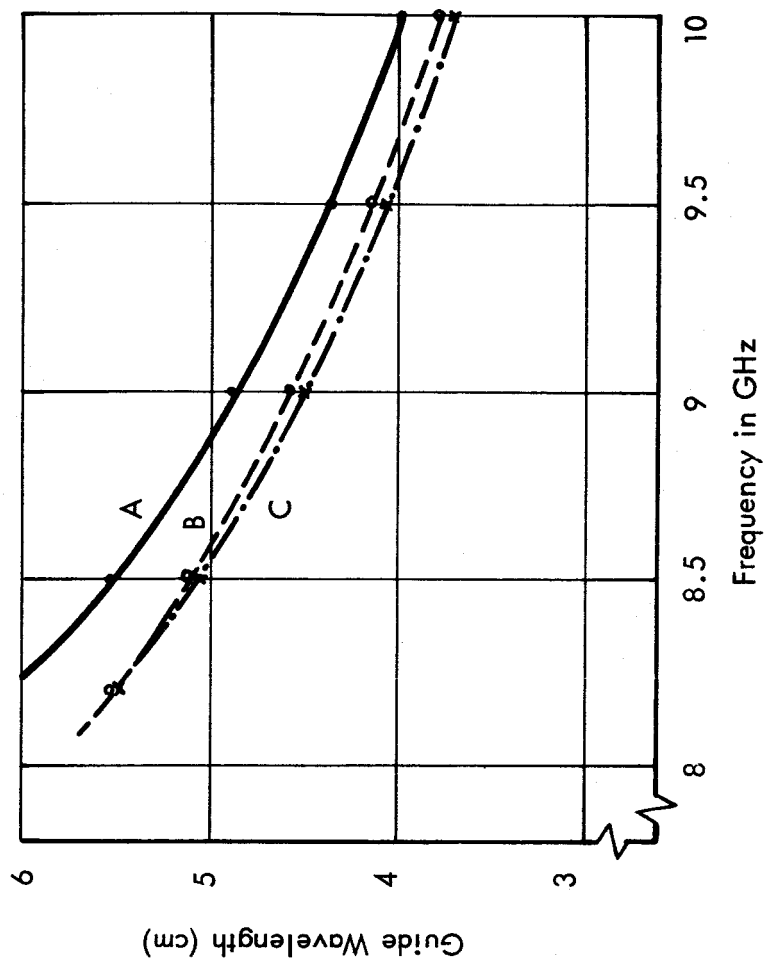


Figure 7 - Guide wave lengths  
 A Parallel walls without grooves.  
 B Groove guide, computed  
 C Groove guide, measured



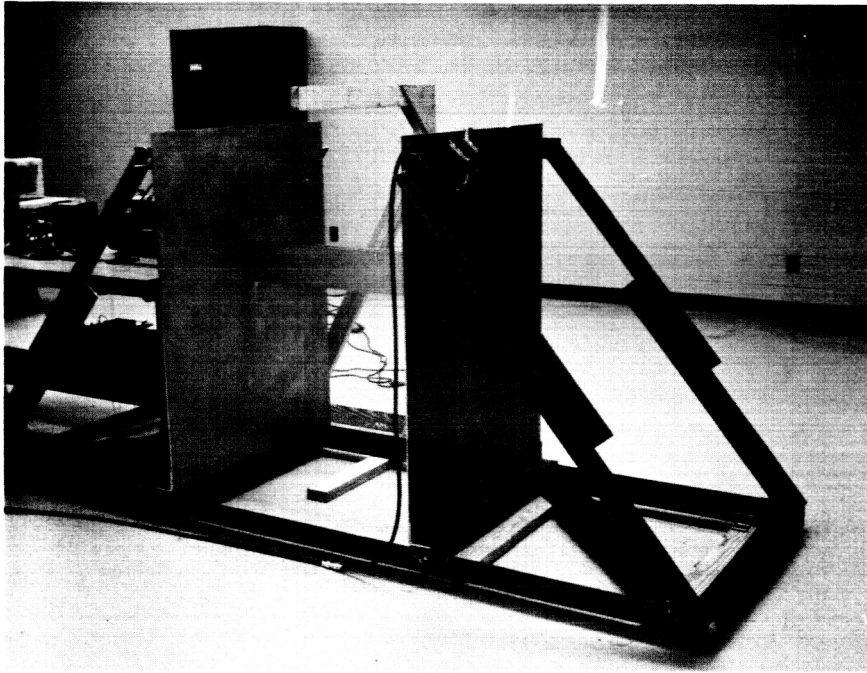


Figure 8 - Groove-guide resonator.

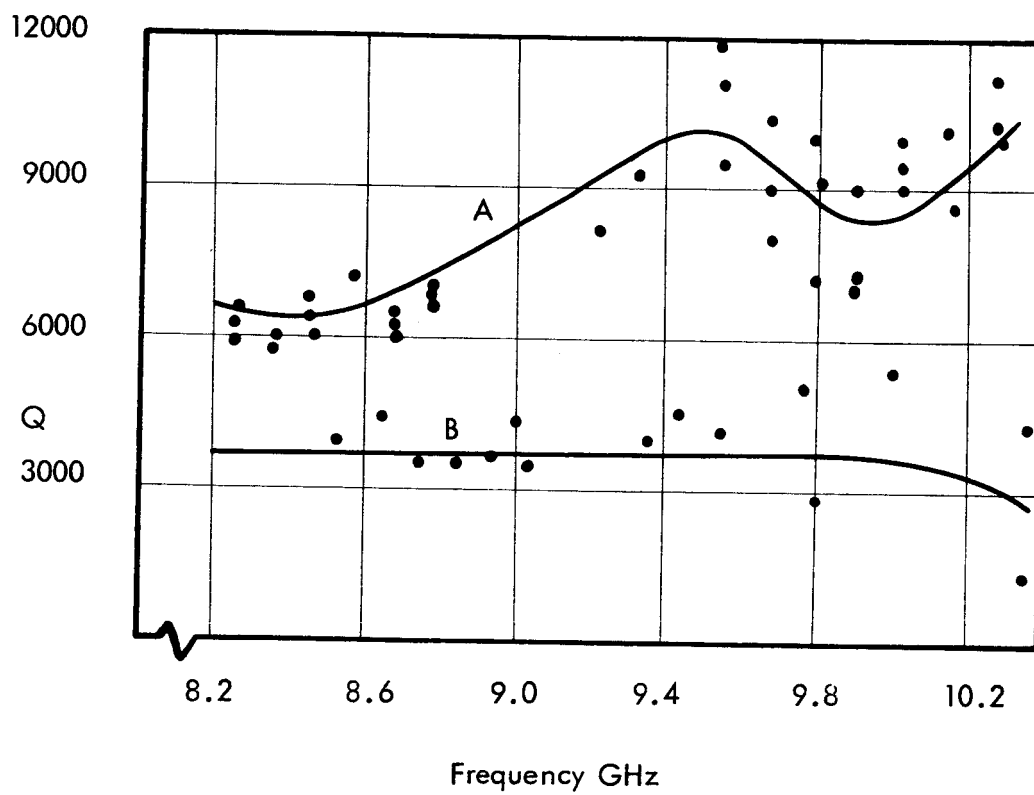


Figure 9 - Q-value versus frequency.  
A Groove-Guide Resonator.  
B Equivalent rectangular guide.

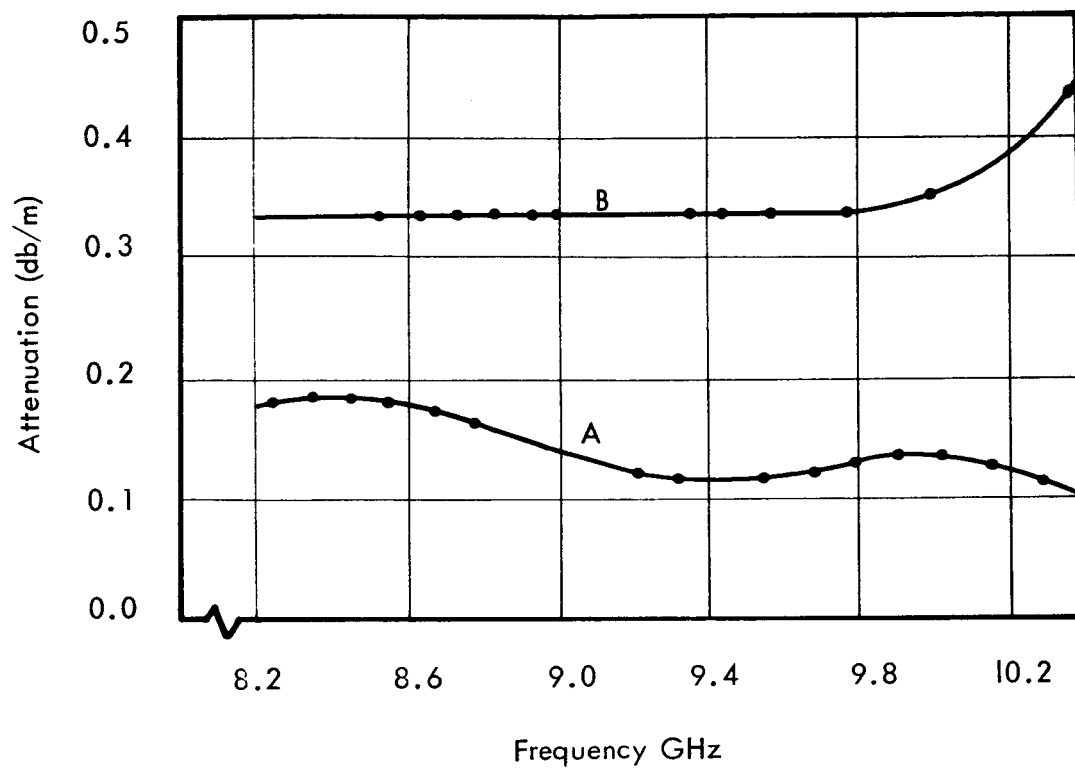


Figure 10 - Attenuation versus frequency.

A Grove guide.

B Rectangular guide.